



Simple Clinical and Behavioral Markers for Early Identification of Development Risk in Preschool Children in Primary Healthcare Settings

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ABSTRACT

Background: The preschool period is a critical window for child growth and development, yet in Indonesia early detection of developmental disturbance in primary care remains suboptimal and tends to focus narrowly on physical growth parameters, while behavioral dimensions of development receive comparatively little attention. **Purpose:** This study aimed to examine simple clinical and behavioral indicators as combined markers for the early identification of developmental risk among preschool children in a primary healthcare setting. **Method:** An analytical observational study with a cross-sectional design was conducted among 110 preschool children aged 3–5 years, recruited through purposive sampling from the catchment area of a primary health care facility. Developmental risk was assessed using the Pre-Screening Developmental Questionnaire (KPSP). Clinical indicators (weight-for-age, height-for-age, mid-upper arm circumference) and behavioral indicators (dietary pattern, physical activity, parental stimulation, and social interaction) were measured and analyzed using chi-square tests and multiple logistic regression. **Result:** Of the 110 children studied, 42 (38.2%) were classified as at risk of developmental disturbance. Bivariate analysis showed that all three clinical indicators and dietary pattern were significantly associated with developmental risk ($p < 0.001$), whereas physical activity, parental stimulation, and social interaction were not ($p > 0.05$). Multivariate analysis confirmed four independent predictors: height-for-age (AOR=4.15), weight-for-age (AOR=3.98), dietary pattern (AOR=3.94), and mid-upper arm circumference (AOR=3.90), together explaining 25% of the variance in developmental risk (Nagelkerke $R^2=0.25$). **Conclusion:** Simple anthropometric measurement combined with a basic dietary-pattern assessment can meaningfully identify preschool children at higher risk of developmental disturbance, supporting the integration of nutritional and developmental screening into a single, low-cost framework for routine use in Posyandu and Puskesmas.

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INTRODUCTION

The preschool period, generally encompassing ages 3 to 5 years, represents an important stage of early childhood during which physical growth, motor competence, language, cognition, socioemotional functioning, and adaptive behavior continue to develop rapidly and interact with one another. Experiences and exposures during early childhood can influence subsequent health, school readiness, educational attainment, and longer-term human development (Susilowati et al., 2022; Fitriahadi & Widyantara, 2026; Khayati et al., 2023). Evidence from life-course research further indicates that developmental adversity during the early years may have persistent consequences for cognitive functioning, educational achievement, health, and productivity in later life (Black et al., 2017; Britto et al., 2017). Consequently, failure to identify developmental difficulties early may delay opportunities for timely intervention and increase the likelihood that developmental problems persist into later childhood (Sofiana et al., 2024; Fitriahadi & Widyantara, 2026).

In Indonesia, growth and developmental monitoring have been incorporated into community- and primary-care

services, particularly through integrated community health posts (Posyandu) and public health centers (Puskesmas) (Astuti, 2018). Community-based developmental monitoring is intended to facilitate early recognition of children who may require additional assessment or intervention, and national resources have increasingly emphasized early detection of growth and developmental problems (Sufa et al., 2023). Nevertheless, implementation within routine services may be constrained by workforce capacity, time limitations, variable familiarity with developmental assessment, and differences in the feasibility of screening procedures. Similar challenges in identifying developmental concerns within routine child-health services have also been reported internationally (Moser et al., 2023). Studies of preschool development further demonstrate that developmental status is multidimensional and cannot be inferred from physical growth alone (Rico-González et al., 2024; Metwally et al., 2023). These considerations highlight the need for pragmatic approaches that complement formal developmental assessment without increasing the burden on primary-care providers.

Anthropometric indicators provide one potential source of readily obtainable information. Weight-for-age and height-for-age are widely used indicators of child growth and

nutritional status within the WHO Child Growth Standards, and they can be assessed using relatively simple equipment in community and primary-care settings (World Health Organization [WHO], 2006). Mid-upper arm circumference (MUAC) is likewise inexpensive and operationally simple, although its interpretation depends on age, purpose, and the cutoff applied. Local community programs have also incorporated anthropometric measurements into child-growth monitoring activities (Kurniawan et al., 2024). Importantly, nutritional status is not only a marker of physical growth but has also been associated with developmental outcomes. Studies among young children have reported associations of stunting and underweight with developmental delay, while dietary diversity and feeding practices may also contribute to variation in developmental outcomes (Oumer et al., 2022; Saleem et al., 2021). These findings provide a rationale for evaluating whether routinely obtainable anthropometric indicators may help identify children who warrant closer developmental attention.

Child development, however, is shaped by more than nutritional and anthropometric conditions. Behavioral and caregiving factors—including dietary quality, opportunities for physical activity, parental stimulation, and social interaction—may influence cognitive, motor, language, and socioemotional development through multiple pathways. Community-based developmental programs in Indonesia have incorporated both developmental stimulation and anthropometric assessment (Delfina et al., 2023), while developmental assessment research has emphasized the importance of evaluating multiple developmental domains rather than relying on a single indicator (Caldera et al., 2023). Physical activity has also been associated with several aspects of cognitive development during early childhood, although findings vary according to study design and measurement approach (Carson et al., 2016). More broadly, evidence on nurturing care emphasizes that adequate nutrition, responsive caregiving, early learning opportunities, safety, and health operate together in supporting optimal development (Britto et al., 2017). Thus, a multidimensional approach may be more informative than consideration of nutritional or behavioral indicators in isolation.

At the same time, the evidence base is methodologically heterogeneous. Studies concerned with early detection and child development use different instruments, constructs, informants, and implementation settings, ranging from developmental assessment tools and quality indicators to caregiver-related measures and motor-screening approaches (Mirsalimi et al., 2020; Hutchins et al., 2023; Scheiber et al., 2025). This heterogeneity is particularly relevant to resource-constrained primary-care settings, where comprehensive developmental instruments may require more time, training, or follow-up than is routinely available. Accordingly, the practical question is not whether simple clinical or behavioral indicators can replace validated developmental assessment, but whether they provide complementary information that may support the identification of children who should receive more detailed developmental evaluation.

The public-health relevance of this question is reinforced by the broader emphasis on early childhood development within national and global development agendas. Developmental monitoring and early detection remain important components of child-health promotion in Indonesia (Syahida & Muryani, 2020; Wijayanti et al., 2025), while the Sustainable Development Goals recognize child health, well-being, education, and human-capital development as interrelated priorities (United Nations [UN], 2024). Broader SDG implementation literature similarly

emphasizes the need to translate global development commitments into feasible interventions that respond to local social and service-delivery conditions (Hirway, 2018; Narayana, 2025). Within this context, strengthening primary-care capacity to recognize children requiring developmental follow-up is relevant not only to child health but also to longer-term educational and social outcomes.

Previous studies have examined nutritional status, growth, caregiving, environmental exposures, and developmental outcomes, but these domains are often assessed using different research frameworks or instruments. Indonesian studies have frequently emphasized growth monitoring, anthropometric assessment, developmental screening, or family-related factors as separate areas of investigation (Sulistyowati & Kayati, 2023; Suprayitno et al., 2022). Therefore, the research gap should not be framed as an absence of studies examining clinical and behavioral determinants together. Rather, there remains limited evidence regarding whether a small set of simple, low-cost, and routinely obtainable clinical and behavioral indicators provides useful complementary information regarding developmental risk within Indonesian primary healthcare settings.

This study is conceptually informed by the Nurturing Care Framework, which describes early childhood development as the product of interacting conditions related to health, adequate nutrition, responsive caregiving, safety and security, and opportunities for early learning (WHO, United Nations Children's Fund [UNICEF], & World Bank Group, 2018). Within this framework, weight-for-age, height-for-age, and MUAC represent indicators primarily related to nutritional and health conditions, whereas dietary pattern, physical activity, parental stimulation, and social interaction reflect aspects of children's daily behavioral and caregiving environments. These variables do not encompass the full Nurturing Care Framework; rather, they constitute a pragmatic subset of routinely or relatively easily obtainable indicators that may be relevant in primary-care practice.

Accordingly, this study aimed to examine the associations between selected clinical indicators—weight-for-age, height-for-age, and MUAC—and behavioral indicators—dietary pattern, physical activity, parental stimulation, and social interaction—and developmental risk among preschool children attending primary healthcare services. The contribution of the study is therefore primarily contextual and implementation-oriented: it evaluates whether a limited set of simple indicators is associated with developmental risk within the Posyandu/Puskesmas context. The study is not intended to establish these indicators as a substitute for standardized developmental assessment or as a validated screening model; rather, it provides preliminary evidence that may inform subsequent prospective model-development and validation studies.

METHODS

Study Design

This study employed an analytical observational design with a cross-sectional approach to examine the associations between selected clinical and behavioral indicators and developmental risk among preschool children. All measurements of developmental status, anthropometric indicators, and behavioral characteristics were obtained during the same study period without longitudinal follow-up.

Accordingly, the analyses were intended to estimate associations rather than temporal, causal, or predictive relationships.

Setting and Participants

The study was conducted at one primary healthcare center (Puskesmas) and its affiliated integrated community health posts (Posyandu) during April–July 2026. The source population comprised preschool children aged 3–5 years residing within the healthcare facility's catchment area. Participants were recruited purposively from children attending routine Posyandu or Puskesmas services during the data-collection period. Children were eligible to participate if they were 3–5 years of age, resided within the designated catchment area, were in a generally stable condition at the time of assessment, and had a parent or legal guardian who provided written informed consent. Children were excluded when they had a severe congenital abnormality or chronic illness that could interfere with the assessment, were unable to complete the required measurements, or had incomplete study data.

Because recruitment was facility-based and purposive, children who did not routinely access Posyandu or Puskesmas services may have been underrepresented. Therefore, the resulting sample should be regarded as a primary-care-based study sample rather than as a representative sample of all preschool children in the wider community. The analytical dataset available for this study contained age eligibility information but did not contain sufficiently detailed sex, family, or sociodemographic variables for inclusion in the present analysis. Consequently, these characteristics were not reconstructed or inferred and could not be incorporated as potential covariates.

Sample Size

The minimum sample size was determined a priori according to the analytical-study calculation documented in the original study protocol. Using a 95% confidence level and a 5% margin of error, the calculation yielded a minimum requirement of 100 participants. An additional 10% was allowed to account for incomplete observations, resulting in a target sample of 110 children. All 110 children included in the analytical dataset were used in the present analysis. The original sample-size calculation was not specifically based on the requirements of multivariable logistic regression. Therefore, the multivariable findings were interpreted cautiously, particularly because 42 participants were classified as having developmental risk and several candidate predictors were considered in the regression analysis. The relatively limited number of outcome events was taken into account when interpreting the precision and stability of the adjusted estimates.

Study Variables

The primary outcome was developmental risk among preschool children. The explanatory variables were grouped into two domains. The clinical indicators consisted of weight-for-age, height-for-age, and mid-upper arm circumference (MUAC). The behavioral indicators consisted of dietary pattern, physical activity, parental stimulation, and social interaction. These variables were examined as correlates of developmental risk rather than as components of a validated diagnostic or prediction model.

Instruments and Measurements

Developmental Risk

Developmental risk was assessed using the Kuesioner Pra-Skrining Perkembangan (KPSP), an age-specific developmental pre-screening instrument used in Indonesian child health services. The KPSP form appropriate to each child's age was administered and scored according to the standard procedure used in the study protocol.

For the present analysis, the analytical dataset contained a prespecified binary KPSP-derived outcome categorized as "at risk" and "not at risk." This existing binary classification was used without additional recoding during the current analysis. KPSP status was treated as the study outcome for examining associations with clinical and behavioral indicators and was not interpreted as a definitive developmental diagnosis. Likewise, the clinical and behavioral variables evaluated in this study were not considered replacements for standardized developmental assessment.

Anthropometric Indicators

Body weight was measured using a calibrated digital weighing scale. Weight-for-age was interpreted according to the WHO Child Growth Standards and expressed as a z-score. For analysis, children with a weight-for-age z-score below -2 SD were classified as undernourished, whereas those with values of -2 SD or higher constituted the reference category. Standing height was measured using a calibrated microtoise or stadiometer according to the measurement procedure applied during data collection. Height-for-age was expressed as a z-score using the WHO Child Growth Standards. Children with height-for-age below -2 SD were classified as stunted, whereas those with values of -2 SD or higher were classified as not stunted.

Mid-upper arm circumference was measured using a standard MUAC tape. According to the operational definition specified in the study protocol, MUAC was categorized as <13.5 cm and ≥ 13.5 cm. The 13.5-cm threshold was used solely as a study-specific operational classification. It should not be interpreted as a WHO diagnostic threshold for acute malnutrition or as a validated cutoff for developmental risk.

Behavioral Indicators

Dietary pattern was assessed using a modified and simplified Food Frequency Questionnaire (FFQ) designed to capture meal frequency and dietary variety. A composite score was derived from the questionnaire and categorized relative to the distribution within the study sample. Scores below the sample median were classified operationally as poor dietary pattern, whereas scores at or above the median were classified as adequate dietary pattern. Because this classification was sample-dependent, the categories were used as analytical groupings rather than clinical dietary thresholds.

Physical activity was assessed through parent-reported information concerning the child's daily duration of physical activity. Reported activity of less than 60 minutes per day was categorized as low physical activity, whereas activity of at least 60 minutes per day was categorized as adequate.

Parental stimulation was assessed using a questionnaire adapted from the Ministry of Health's early childhood stimulation, detection, and intervention guidance (SDIDTK). The questionnaire covered stimulation related to motor, language, and social development. The resulting scores were categorized relative to the sample median, with values below the median classified as poor stimulation and those at or above the median classified as adequate stimulation.

Social interaction was assessed using a parent-reported questionnaire addressing social responsiveness and communication. Scores were similarly dichotomized using the sample median into poor and adequate social interaction. The behavioral measures were adapted for the purposes of this study. Formal psychometric validation and reliability coefficients were not available in the analytical dataset used for the present report. Consequently, these measures were treated as operational study variables rather than validated behavioral screening instruments. This measurement limitation was considered when interpreting both significant and non-significant associations.

Data Analysis

Data were checked for completeness and internal consistency before coding and analysis. Records that did not meet the eligibility criteria or contained incomplete information required for the principal analyses were excluded according to the study protocol. Descriptive analysis was used to summarize developmental-risk status and the distribution of clinical and behavioral indicators. Categorical variables were presented as frequencies and percentages. Continuous variables, where available and appropriate, were summarized using descriptive statistics.

Bivariate associations between each categorical clinical or behavioral indicator and developmental risk were examined using the Pearson chi-square test. Crude odds ratios (ORs) with 95% confidence intervals (CIs) were calculated to estimate the magnitude and precision of the associations. Statistical significance was evaluated using two-sided *p*-values. Variables with a bivariate *p*-value <0.25 were considered for inclusion in the multiple logistic regression analysis. The multivariable analysis was used to estimate adjusted associations between the candidate indicators and developmental risk. Results were expressed as adjusted odds ratios (AORs) with 95% CIs and corresponding *p*-values, with *p*<0.05 considered statistically significant.

Because the study employed a cross-sectional design, the ORs and AORs were interpreted as measures of association rather than evidence of causality or prospective prediction. Differences in the numerical magnitude of AORs were also not interpreted as evidence that one factor was definitively more important than another when confidence intervals were wide and overlapping. Nagelkerke pseudo-*R*² was reported as an indicator of overall model explanatory performance.

Ethical Considerations

Ethical approval for the study was obtained from the Health Research Ethics Committee of Universitas Muhammadiyah Gombong under protocol number 21125000004. Data collection was conducted from April to July 2026. Before participation, parents or legal guardians received an explanation of the study objectives, procedures, potential benefits and risks, voluntary nature of participation, confidentiality protections, and their right to withdraw without consequences. Written informed consent was obtained from the parent or legal guardian before any study assessment was conducted. Participant-identifying information was removed or coded to protect confidentiality. Study data were used solely for research purposes and handled in accordance with the approved research protocol and applicable ethical requirements for research involving children.

RESULTS OF STUDY

A total of 110 preschool children were included in the analysis. Of these, 42 children (38.2%) were classified as being at developmental risk, whereas 68 (61.8%) were classified as not at risk. Regarding anthropometric indicators, 51 children (46.4%) were classified as undernourished based on weight-for-age, 50 (45.5%) were stunted based on height-for-age, and 44 (40.0%) had low mid-upper arm circumference (MUAC). Among the behavioral indicators, 58 children (52.7%) were classified as having a poor dietary pattern, 48 (43.6%) had low reported physical activity, 45 (40.9%) had poor parental stimulation, and 49 (44.5%) had poor social interaction (Table 1). Because the participants were recruited purposively from children attending primary healthcare services, these proportions describe the characteristics of the study sample and should not be interpreted as population prevalence estimates.

Table 1. Distribution of Clinical and Behavioral Indicators and Developmental Risk Among Preschool Children (*n* = 110)

Variable	n	%
Developmental status		
At risk	42	38.2
Not at risk	68	61.8
Weight-for-age		
Undernourished	51	46.4
Normal/reference category	59	53.6
Height-for-age		
Stunted	50	45.5
Not stunted/reference category	60	54.5
Mid-upper arm circumference (MUAC)		
Low	44	40.0
Reference category	66	60.0
Dietary pattern		
Poor	58	52.7
Adequate	52	47.3
Physical activity		
Low	48	43.6
Adequate	62	56.4
Parental stimulation		
Poor	45	40.9
Adequate	65	59.1
Social interaction		
Poor	49	44.5
Adequate	61	55.5

Pearson chi-square analyses identified statistically significant associations between developmental risk and four study variables (Table 2). Children classified as undernourished according to weight-for-age had approximately 3.9 times the odds of being classified as developmentally at risk compared with the reference group (OR=3.91; 95% CI: 1.73–8.84; *p*<.001). Stunted children also had higher odds of developmental risk than non-stunted children (OR=3.52; 95% CI: 1.57–7.89; *p*=.002). Similarly, low MUAC was associated with higher developmental risk (OR=3.79; 95% CI: 1.68–8.55; *p*=.001), and children classified as having a poor dietary pattern had higher odds of developmental risk than those with an adequate dietary pattern (OR=3.57; 95% CI: 1.56–8.15; *p*=.002).

In contrast, low physical activity was not significantly associated with developmental risk (OR=1.78; 95% CI: 0.82–3.87; *p*=.146). No statistically significant associations were

observed for poor parental stimulation (OR=1.33; 95% CI: 0.61–2.91; $p=.468$) or poor social interaction (OR=1.67; 95% CI: 0.77–3.63; $p=.194$). The confidence intervals for these three behavioral indicators included the null value of 1.00; therefore, the findings do not provide sufficient evidence of statistically significant associations in this sample. Based on the prespecified criterion of $p<.25$, six variables were eligible for consideration in the multivariable analysis: weight-for-age, height-for-age, MUAC, dietary pattern, physical activity, and social interaction. Parental stimulation did not meet this criterion ($p=.468$).

In the reported final multiple logistic regression model, four variables remained statistically associated with developmental risk after adjustment: undernourished weight-for-age (AOR=3.98; 95% CI: 1.11–14.29; $p=.034$), stunted height-for-age (AOR=4.15; 95% CI: 1.20–14.33;

$p=.025$), low MUAC (AOR=3.90; 95% CI: 1.16–13.08; $p=.028$), and poor dietary pattern (AOR=3.94; 95% CI: 1.03–15.03; $p=.044$) (Table 3).

The adjusted effect estimates were similar in magnitude, ranging from 3.90 to 4.15. However, all four estimates had relatively wide and substantially overlapping confidence intervals. Therefore, the results do not provide sufficient statistical evidence to rank any of these variables as a stronger associated factor than the others. The relatively wide confidence intervals also indicate limited precision of the adjusted estimates. The reported Nagelkerke pseudo- R^2 was 0.25. This value indicates modest overall explanatory performance of the fitted logistic model but should not be interpreted as indicating that the model literally “explained 25% of the variance” in developmental risk in the same manner as an R^2 statistic from linear regression.

Table 2. Bivariate Associations Between Clinical and Behavioral Indicators and Developmental Risk in Preschool Children

Variable	At risk, n (%)	Not at risk, n (%)	OR	95% CI	Pearson χ^2	p-value
Weight-for-age						
Undernourished	28 (54.9)	23 (45.1)	3.91	1.73–8.84	11.262	<.001*
Normal	14 (23.7)	45 (76.3)	1.00	—	—	—
Height-for-age						
Stunted	27 (54.0)	23 (46.0)	3.52	1.57–7.89	9.717	.002*
Normal	15 (25.0)	45 (75.0)	1.00	—	—	—
MUAC						
Low	25 (56.8)	19 (43.2)	3.79	1.68–8.55	10.791	.001*
Normal	17 (25.8)	49 (74.2)	1.00	—	—	—
Dietary pattern						
Poor	30 (51.7)	28 (48.3)	3.57	1.56–8.15	9.533	.002*
Adequate	12 (23.1)	40 (76.9)	1.00	—	—	—
Physical activity						
Low	22 (45.8)	26 (54.2)	1.78	0.82–3.87	2.112	.146
Adequate	20 (32.3)	42 (67.7)	1.00	—	—	—
Parental stimulation						
Poor	19 (42.2)	26 (57.8)	1.33	0.61–2.91	0.527	.468
Adequate	23 (35.4)	42 (64.6)	1.00	—	—	—
Social interaction						
Poor	22 (44.9)	27 (55.1)	1.67	0.77–3.63	1.689	.194
Adequate	20 (32.8)	41 (67.2)	1.00	—	—	—

OR: odds ratio; CI: confidence interval; Ref: reference category. * $p < 0.05$ (statistically significant).

Table 3. Reported Multiple Logistic Regression Estimates for Factors Associated with Developmental Risk

Variable	AOR	95% CI	p-value
Weight-for-age (undernourished vs normal)	3.98	1.11–14.29	0.034*
Height-for-age (stunted vs normal)	4.15	1.20–14.33	0.025*
MUAC (low vs normal)	3.90	1.16–13.08	0.028*
Dietary pattern (poor vs adequate)	3.94	1.03–15.03	0.044*

AOR, adjusted odds ratio; CI, confidence interval; MUAC, mid-upper arm circumference. * $p<.05$.

DISCUSSION

The present study found that 42 of 110 preschool children (38.2%) were classified as being at developmental risk. Because the participants were recruited purposively from children attending a single primary healthcare setting, this

proportion should be interpreted as a characteristic of the study sample rather than as an estimate of population prevalence. Previous studies have nevertheless demonstrated that suspected developmental delay is an important concern in preschool and under-five populations, although reported proportions vary considerably according to population

characteristics, developmental instruments, and case definitions (Metwally et al., 2023; Oumer et al., 2022). Developmental outcomes are also influenced by the quality of children's learning and care environments; for example, evidence from preschool settings has demonstrated that improvements in the quality of educational interactions may contribute to better cognitive development (Andrew et al., 2024). Accordingly, the relatively high proportion observed in the present study reinforces the importance of developmental monitoring in primary-care populations but should not be generalized beyond the study setting.

Weight-for-age, height-for-age, and MUAC remained independently associated with developmental risk in the multivariable model. These findings are consistent with a broader body of evidence linking inadequate nutritional status with poorer developmental outcomes. In Southwest Ethiopia, Oumer et al. (2022) reported that stunting and underweight were independently associated with developmental delay among children aged 12–59 months. Similarly, Mustakim et al. (2022), in a study of Indonesian children aged 1–3 years, found that stunted children were more likely to demonstrate suspected developmental delay than their non-stunted counterparts. A prospective cohort involving Cambodian children further demonstrated that stunting and wasting during early childhood were associated with delayed acquisition of multiple motor and cognitive milestones (Van Beekum et al., 2022). Systematic evidence also suggests that nutritional interventions and adequate nutrient provision may contribute to cognitive development during the preschool years, although effects vary according to intervention type, timing, baseline nutritional status, and developmental outcome assessed (Roberts et al., 2022).

The association between poor anthropometric status and developmental risk is biologically plausible. Early brain development depends on adequate energy, protein, essential fatty acids, iron, iodine, zinc, and other micronutrients that contribute to neuronal proliferation, synaptogenesis, myelination, neurotransmitter function, and structural brain development (Prado & Dewey, 2014). Nutritional deficits during sensitive periods may therefore affect both neural maturation and children's capacity to engage effectively with their physical and social environments. However, anthropometric indicators should be interpreted primarily as markers of nutritional and growth conditions rather than as direct measures of neurodevelopment. Child development remains multidimensional and reflects interactions between nutritional, biological, environmental, and experiential influences.

The association observed for MUAC requires particularly cautious interpretation. MUAC is operationally simple and inexpensive to measure, making it attractive in community and primary-care settings. Nevertheless, the <13.5-cm cutoff used in this study was a study-specific operational threshold rather than a validated developmental-risk threshold. Therefore, the present findings indicate an association between the study-defined MUAC category and developmental risk, but they do not establish 13.5 cm as a clinically valid cutoff for developmental screening. Moreover, the simultaneous inclusion of weight-for-age, height-for-age, and MUAC means that these anthropometric indicators may capture overlapping aspects of nutritional status. Confirmation of their independent contributions would benefit from explicit evaluation of multicollinearity and replication in larger samples.

Among the behavioral indicators, poor dietary pattern remained independently associated with developmental risk (AOR=3.94; 95% CI: 1.03–15.03). This finding is broadly

consistent with studies suggesting that dietary diversity and nutritional quality are related to cognitive and developmental outcomes. In rural China, Li et al. (2021) reported that preschool children with more diverse diets performed better on measures of working memory and verbal comprehension. More recent longitudinal evidence has similarly linked greater dietary diversity with better cognitive outcomes during early childhood. Oumer et al. (2022) also identified low dietary diversity as an independent factor associated with developmental delay.

Evidence from Ethiopia further illustrates that inadequate dietary diversity remains common among preschool populations. Keyata et al. (2022) found that a large proportion of preschool children attending selected kindergarten schools had low dietary diversity, although that study primarily examined determinants of dietary diversity rather than developmental outcomes. Thus, it provides important nutritional context but should not be interpreted as direct evidence of a causal dietary-diversity–development relationship.

The biological plausibility of the present association is supported by evidence that adequate nutrition contributes to brain development through several pathways, including neuronal differentiation, synaptic development, myelination, and neurotransmitter synthesis (Prado & Dewey, 2014). Systematic reviews of nutritional interventions among preschool children also indicate that nutritional status and specific dietary interventions may influence cognitive development, although findings are heterogeneous (Roberts et al., 2022). Broader literature on cognitive development likewise emphasizes that preschool cognition develops through dynamic interactions among biological, environmental, learning, and experiential factors (Muqaddasxon, 2024).

Nevertheless, the present dietary finding should be interpreted cautiously. Dietary pattern was measured using a modified, simplified FFQ and dichotomized according to the sample median rather than a clinically validated dietary threshold. Consequently, “poor” dietary pattern in this study represents a relative classification within the study population and should not be interpreted as a diagnostic category of dietary inadequacy. The wide confidence interval around the adjusted estimate also indicates substantial statistical uncertainty.

Physical activity, parental stimulation, and social interaction were not statistically associated with developmental risk in the present analysis. These null findings should not be interpreted as evidence that these domains have no role in child development. Rather, they should be considered in light of measurement characteristics, statistical power, and the cross-sectional design.

Evidence regarding physical activity and cognitive development during early childhood remains heterogeneous. Carson et al. (2016), in a systematic review, found some evidence of favorable associations between physical activity and cognitive development, but differences in study designs and measurement methods limited firm conclusions. Malambo et al. (2022) similarly reported heterogeneous evidence regarding associations among physical activity, motor competence, physical fitness, and executive functions in preschool children. In the present study, physical activity was assessed through brief parent report rather than objective measures such as accelerometry, potentially introducing recall error and reducing sensitivity to differences in activity intensity, frequency, and type.

Behavioral exposure during early childhood is also more complex than the amount of physical activity alone. For

example, a systematic review and meta-analysis by Mallawaarachchi et al. (2024) demonstrated that the context of screen use—including content, background television, and caregiver co-use—was associated with cognitive and psychosocial outcomes. Although screen exposure was not examined in the present study, these findings illustrate that developmental effects may depend on the quality and context of children's behavior rather than on simple duration-based categories.

The non-significant finding for parental stimulation likewise requires caution. Responsive caregiving and opportunities for learning are central components of early childhood development within the Nurturing Care Framework (World Health Organization [WHO], United Nations Children's Fund [UNICEF], & World Bank Group, 2018). Indonesian research has also reported associations between maternal psychosocial stimulation and child development. Amelia et al. (2023), using KPSP to assess development and a HOME-based measure of psychosocial stimulation, identified a significant relationship between maternal stimulation and developmental status among children aged 3–5 years. Family involvement has similarly been associated with preschool growth and development in Indonesian populations (Suprayitno et al., 2022).

Other studies further illustrate the importance of the social and caregiving environment. Parenting style has been associated with several dimensions of preschool development (Han & Yan, 2025), including moral development in Indonesian preschool children (Zatihulwani, 2025). Play-based and role-playing activities have also been linked to improvements in social and emotional development (San et al., 2021; Wirahandayani et al., 2023). Preschool quality and teacher–child interaction can influence cognitive outcomes (Andrew et al., 2024), while concerns regarding language development and social competence are associated with children's social participation (Doove et al., 2021). Collectively, these findings indicate that social and caregiving experiences remain developmentally relevant even though the simplified parental-stimulation and social-interaction indicators used in the present study did not reach statistical significance.

The discrepancy between previous evidence and the present null findings may partly reflect measurement limitations. The stimulation and social-interaction instruments used in this study were adapted measures without available formal psychometric validation, and their scores were dichotomized using sample medians. Dichotomization may reduce information and statistical sensitivity, particularly in a relatively small sample. Parent-reported measures may also be affected by recall and social-desirability bias. Moreover, the confidence intervals for physical activity and social interaction included potentially meaningful positive associations, indicating that absence of statistical significance should not be equated with evidence of no effect.

Socioeconomic and family-related factors may provide an additional explanation. Alijanzadeh et al. (2024) demonstrated that growth and developmental delay can vary according to socioeconomic conditions, while broader child-development literature emphasizes the importance of family and environmental determinants. These variables were not sufficiently available in the present analytical dataset. Consequently, residual confounding by parental education, household socioeconomic status, maternal employment, birth history, prematurity, feeding history, and other caregiving characteristics cannot be excluded. The data also do not support a conclusion that nutritional status mediates the

relationship between behavioral factors and developmental risk because no formal mediation analysis was conducted.

The final logistic regression model yielded a Nagelkerke pseudo- R^2 of 0.25. This should be interpreted as indicating modest explanatory performance of the model rather than as meaning that the four variables literally “explained 25% of the variance” in developmental risk in the same manner as an R^2 value from linear regression. The finding is consistent with the multidimensional nature of child development, which is shaped by interacting nutritional, health, caregiving, socioeconomic, environmental, and learning-related determinants.

The adjusted odds ratios for weight-for-age, height-for-age, MUAC, and dietary pattern were similar in magnitude, but all had relatively wide and overlapping confidence intervals. The results therefore do not provide sufficient evidence to rank any one indicator as a stronger associated factor than the others. The width of the intervals also suggests limited precision, which is plausible given the relatively small sample, the 42 developmental-risk events, and the number of candidate variables considered for multivariable analysis. These considerations increase the importance of replication in larger samples.

Furthermore, several potentially relevant confounders were unavailable in the analytical dataset. Socioeconomic conditions have been associated with growth and developmental outcomes (Alijanzadeh et al., 2024), while parenting, family involvement, and the broader learning environment have also been linked to preschool development (Han & Yan, 2025; Suprayitno et al., 2022; Zatihulwani, 2025). Their omission may have resulted in residual confounding and may partly account for the unexplained component of developmental risk.

Implications for Primary Healthcare

The findings have potential relevance for primary healthcare because weight, height, MUAC, and basic dietary information can be obtained relatively easily during routine child-health contacts. However, the present study was designed to examine associations rather than diagnostic or predictive performance. The findings therefore do not demonstrate that these indicators can independently discriminate children with and without developmental problems, nor do they establish sensitivity, specificity, calibration, or predictive accuracy.

The practical implication is that anthropometric and dietary information may provide complementary contextual information when evaluating preschool children, but it should not replace standardized developmental assessment. Indonesian studies have demonstrated the feasibility and importance of developmental monitoring using KPSP and related approaches in community and primary-care contexts (Ibrahim et al., 2024; Maheswari et al., 2025). Accordingly, the present results are better interpreted as supporting closer integration between routine nutritional assessment and established developmental monitoring rather than as proposing a new screening instrument.

This interpretation is also consistent with the Nurturing Care Framework, which conceptualizes child development as the product of interacting conditions involving health, adequate nutrition, responsive caregiving, safety and security, and opportunities for early learning (WHO, UNICEF, & World Bank Group, 2018). The present study captured only a limited subset of these domains. Its contribution therefore lies primarily in demonstrating that several readily obtainable clinical and dietary indicators were associated with

developmental risk within a Posyandu/Puskesmas context, rather than in establishing a validated combined predictive model. Existing Indonesian community initiatives involving KPSP and developmental monitoring similarly support the value of strengthening early identification within routine community services (Maheswari et al., 2025).

Strengths and Limitations

A strength of this study is the simultaneous examination of several routinely obtainable anthropometric indicators together with selected behavioral factors in a primary-care population. This approach reflects the multidimensional perspective increasingly emphasized in early childhood development research and may provide useful preliminary evidence for designing subsequent prospective studies.

Several limitations, however, should be considered. First, the cross-sectional design prevents determination of temporal sequence and does not support causal inference. Poor nutritional status may contribute to developmental difficulties, but developmental or health problems may also influence feeding, physical activity, and growth. Second, purposive recruitment from a single primary-care catchment limits representativeness and external validity. The 38.2% developmental-risk proportion should therefore not be interpreted as a population prevalence estimate.

Third, detailed child sex, parental education, socioeconomic characteristics, birth history, prematurity, and other potentially important confounders were not available for analysis. Residual confounding is therefore likely. Fourth, the dietary, physical-activity, parental-stimulation, and social-interaction variables were derived from simplified parent-reported measures for which formal psychometric validity and reliability information was not available. Median-based dichotomization of several behavioral variables may also have reduced measurement sensitivity.

Fifth, the MUAC cutoff of 13.5 cm was a study-specific operational threshold and should not be interpreted as a validated clinical cutoff for developmental risk. Sixth, several anthropometric indicators included in the model measure related dimensions of nutritional status; without documented multicollinearity diagnostics, their statistical independence cannot be fully established. Seventh, the relatively limited number of developmental-risk events and the wide confidence intervals of the adjusted estimates suggest that the multivariable model may have limited stability.

Finally, developmental status was analyzed as a binary KPSP-derived outcome. Although KPSP is used for developmental pre-screening in Indonesian child-health services, dichotomization may reduce information contained in the original developmental classification. Local research comparing KPSP with other developmental-screening approaches has highlighted its utility for early detection while also emphasizing the importance of appropriate interpretation of screening results (Ibrahim et al., 2024).

Future research should therefore employ prospective, multicenter designs with larger and more representative samples; validated measures of dietary intake, physical activity, stimulation, and social interaction; systematic assessment of major confounders; and explicit evaluation of multicollinearity and model stability. If a combined risk-stratification model is subsequently developed, it should undergo internal validation, discrimination and calibration assessment, and external validation before being considered for routine clinical or community screening.

CONCLUSIONS AND RECOMMENDATION

Undernourished weight-for-age, stunted height-for-age, low MUAC, and poor dietary pattern were independently associated with developmental risk among preschool children, whereas physical activity, parental stimulation, and social interaction were not statistically significant. These findings suggest that simple anthropometric and dietary indicators may complement standardized developmental assessment in primary healthcare settings. However, they should not be considered validated screening or prediction tools. Further prospective studies with larger, multicenter samples and validated behavioral measures are needed before routine implementation in Posyandu or Puskesmas.

DECLARATION

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Conflicts of Interest

The authors declare that they have no conflicts of interest related to this study.

Ethics Approval and Consent to Participate

This study was conducted in accordance with the ethical principles governing research involving human participants. Ethical approval was obtained from the Health Research Ethics Committee of Universitas Muhammadiyah Gombong under protocol number 21125000004. Written informed consent was obtained from the parents or legal guardians of all participating children before data collection. Participation was voluntary, and confidentiality and anonymity were maintained throughout the study.

Consent for Publication

The manuscript does not contain any identifiable individual data, including images, videos, or personal information.

Availability of Data and Materials

The datasets generated and/or analyzed during the current study are available from the corresponding author upon reasonable request.

Artificial Intelligence-Assisted Technology

The authors acknowledge the use of ChatGPT (OpenAI) as an artificial intelligence-assisted tool during manuscript preparation. ChatGPT was used to support language refinement, grammar checking, sentence restructuring, and manuscript formatting. It was not used to generate research data, perform statistical analyses, make independent scientific interpretations, or replace the authors' scientific judgment. All AI-assisted outputs were critically reviewed, edited, and verified by the authors. The authors remain fully responsible for the accuracy, integrity, interpretation, and final content of the manuscript.

Authors' Contributions

Juni Sofiana led the conceptualization of the study, developed the research design, conducted data collection, performed the data analysis, and prepared the initial draft of the manuscript. Lutfia Uli Na' mah provided methodological guidance throughout the study, contributed to the interpretation of the findings, and critically revised the manuscript for important intellectual content. Eka Novyriana contributed to the statistical analysis, supported the validation of the results, and assisted in refining the manuscript. Wulan Rahmadhani supervised the overall research process, reviewed the final version of the manuscript, and approved it for publication.

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